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Research Article

Rediscovery of *Euxinopetalum dobatorum* Hoffman, 1973 (Diplopoda, Callipodida, Schizopetalidae) in Turkey

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Abstract

A remarkable dwarf schizopetalid, *Euxinopetalum dobatorum* Hoffman, 1973, is rediscovered in the Heracles Cave (type locality) in Turkey. This poorly known species is recorded after more than 50 years and is illustrated here with photographs, photomicrographs, and scanning electron micrographs, including descriptive notes and remarks. The small body size and the reduced number of body segments in Callipodida are briefly discussed, while the question about the type locality is clarified.

Key words: Anatolia, biospeleology, Black Sea, cave, Euxinopetalinae, millipedes

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Introduction

The millipede fauna of Turkey is still poorly known, although it has been studied by various authors over the last century. So far, just about 140 species are known from the region (Enghoff 2006; Antić 2023). Only a small part of this number belongs to the order Callipodida. To date, 18 species from five genera and two families, Dorypetalidae (three species) and Schizopetalidae (15 species), are known from this area (Hoffman and Lohmander 1964; Hoffman 1973; Enghoff 2006; Stoev et al. 2008).

One of the very interesting taxa from Turkey is undoubtedly a tiny schizopetalid *Euxinopetalum dobatorum* Hoffman, 1973. The small size, reduced number of body segments, undivided hypoproct, characteristics of gonopods, and the presence of the rudimentary leg pair 2 in females make this species very particular within the family Schizopetalidae. For this reason, Hoffman (1973: 85) even established a new subfamily, Euxinopetalinae, for his "remarkable new form".

Euxinopetalum dobatorum is only known from the original description, based on a male and a female from two caves in the Zonguldak Province (Hoffman 1973). Here, we report the rediscovery of this species half a century after its description and present new illustrations and descriptive notes.

Materials and methods

Preservation, dissecting, imaging

Specimens preserved in 70% ethanol were examined with a Nikon SMZ745T, a Nikon SMZ1270, and a Zeiss Stemi 2000-C binocular stereo microscopes (IZB). Pictures of the habitual structures were taken using a Nikon DS-Fi2 camera with a Nikon DS-L3 camera controller attached to a Nikon SMZ1270 binocular stereo microscope (IZB). The gonopods were dissected and mounted in glycerin for temporary microscope preparations and observed with a Carl Zeiss Axioscope 40 microscope (IZB). Pictures of the gonopods were taken with a Canon PowerShot A80 digital camera connected to a Carl Zeiss Axioscope 40 microscope (IZB). For some images, focal stacking was completed with Zerene Stacker Professional v1.04. Drawings of the gonopods were obtained using tracing paper placed on a computer monitor displaying the pictures of those structures made in a previously described way. Pictures of live animals by M.E. were taken with a Nikon D7000 camera with a Nikon AF-S VR Micro Nikkor 105mm f/2.8G IF ED lens. For scanning electron microscopy (SEM), samples were dehydrated in an ascending alcohol series (80%, 90%, 96% EtOH for 10–15 min each), then acetone and air dried. The samples were mounted on aluminum stubs equipped with sticky aluminum tape, coated with platinum (Leica EM SCD500), and studied with a JEOL JSM 6610-LV scanning electron microscope at an accelerating voltage of 15 kV (NHMW). After the SEM examination, all parts were placed back in ethanol. The final images were processed and assembled with Adobe Photoshop CS.

Abbreviations

c – coxa;
cp – coxal process;
dl – digitiform rounded lobe;
l – lamella;
mp – medial process;
s – solenomere;
t – telopodite;
tp – trifurcated mesal process;

ABBM – Biodiversity Science Museum, Atatürk University, Erzurum, Turkey;
IZB – Institute of Zoology, University of Belgrade – Faculty of Biology, Belgrade, Serbia;
NHMW – Naturhistorisches Museum Wien, Vienna, Austria.

Results

Taxonomy

Class Diplopoda de Blainville in Gervais 1844
Order Callipodida Pocock, 1894
Family Schizopetalidae Verhoeff, 1909

Genus *Euxinopetalum* Hoffman, 1973

Type and only species. *Euxinopetalum dobatorum* Hoffman, 1973, by original designation.

Diagnosis. Differs from all other genera of the family Schizopetalidae by the presence of the rudimentary leg pair 2 in the females (vs leg pair 2 normal in other genera). It also differs from all other Schizopetalidae genera, with the ex-

ception of the genus *Himatiopetalum* Verhoeff, 1900, by the presence of an undivided hypoproct (vs hypoproct divided into three subsclerites in other genera).

In addition, this is one of the smallest callipodids, with a length of 13–15 mm in males and 15.5–23 mm in females, and with the lowest known number of segments recorded in the order, 36 and 38 in adults. Gonopods relatively simple, without sternal remnants; telopodites attached to coxa posteriorly, main stem columnar, simple and straight, distally with several processes; coxal process simple and sigmoid.

***Euxinopetalum dobatorum* Hoffman, 1973**

Figs 1–5

Euxinopetalum dobatorum Hoffman, 1973: 86, figs 1–4; Enghoff 2006: 188; Stoev et al. 2008: 32.

Material examined. TURKEY • 3 males, 1 female; Zonguldak Province, Ereğli District, Herakles Cave (= "Höhle 2 bei Ereğli", = "Cave Nr. 2, Indere, 2 km northwest of Ereğli"), part of Cehennem Ağzı Caves; N41.291725, E31.411989; 35 m a.s.l.; 18 Aug. 2020; leg. M. Elverici; ABBM (1 male, 1 female), IZB (1 male), NHMW MY10517 (1 male).

Diagnosis. As for the genus.

Descriptive notes (based on new samples). Living animals brownish-grey (Fig. 1A, B). Ommatidia black (Fig. 2C). Female with a pair of white anterodorsal spots on segment 3 (Fig. 1A, B). Body with 36 segments (including telson) in all four specimens (Fig. 2A). Males 13–13.5 mm long, vertical diameter of the highest segment 1 mm. Female 15 mm long, vertical diameter of the highest segment 1.5 mm. Head setose, without modifications, with 33–35 ommatidia arranged in subtriangular field; labrum and gnathochilarium normal (Fig. 2C–G). Antennae 2.2 mm long (in male 13.5 mm long); antennomere 5 with distodorsal area of sensilla basiconica; antennomere 6 with distal oreola of sensilla basiconica in several rows. Metazonae with ca. 16+16 longitudinal crests (Fig. 2F, H). Ozopores opening on anterior ends between the 4th and 5th crests (Fig. 2F, H). Paraprocts subdivided, with 2+2 setae; hypoproct single with 4 setae (Fig. 2B). Leg pairs 1–3 in males, and 1 and 3 in females with tarsal combs. In males leg pairs 3–7 and 9–12 with visible coxal vesicles; coxa 2 with gonopore located on posterior side; leg pairs 4–7 without tarsal claws (one leg 4 with very reduced claw), tarsi with modified ventral setae in distal two-thirds (Fig. 3A–D); all podomeres with very long and densely setose ventral setae. In female leg pairs 3–12 with visible coxal vesicles; leg pair 2 vestigial, triangular with coxa and one podomere covered by long setae (Fig. 3E, F).

Gonopods (Figs 4 and 5). Parallel to each other; partly protruding outside the segment 7. Without sternum. Coxa (c) well developed. Coxal processes (cp) sigmoid, curved anteriad, twice as short as telopodites (t) with a few long proximomesal setae. Telopodite columnar, relatively simple, distally bifurcated. Lateral branch higher, with digitiform rounded lobe (dl) with five setae on mesal surface and minute setulae on outer surface, and posteromesal acuminate or bifurcated lamella (l). Setulae also present in outer central part of telopodite. Mesal branch with three processes: solenomere (s) as the most lateral one,

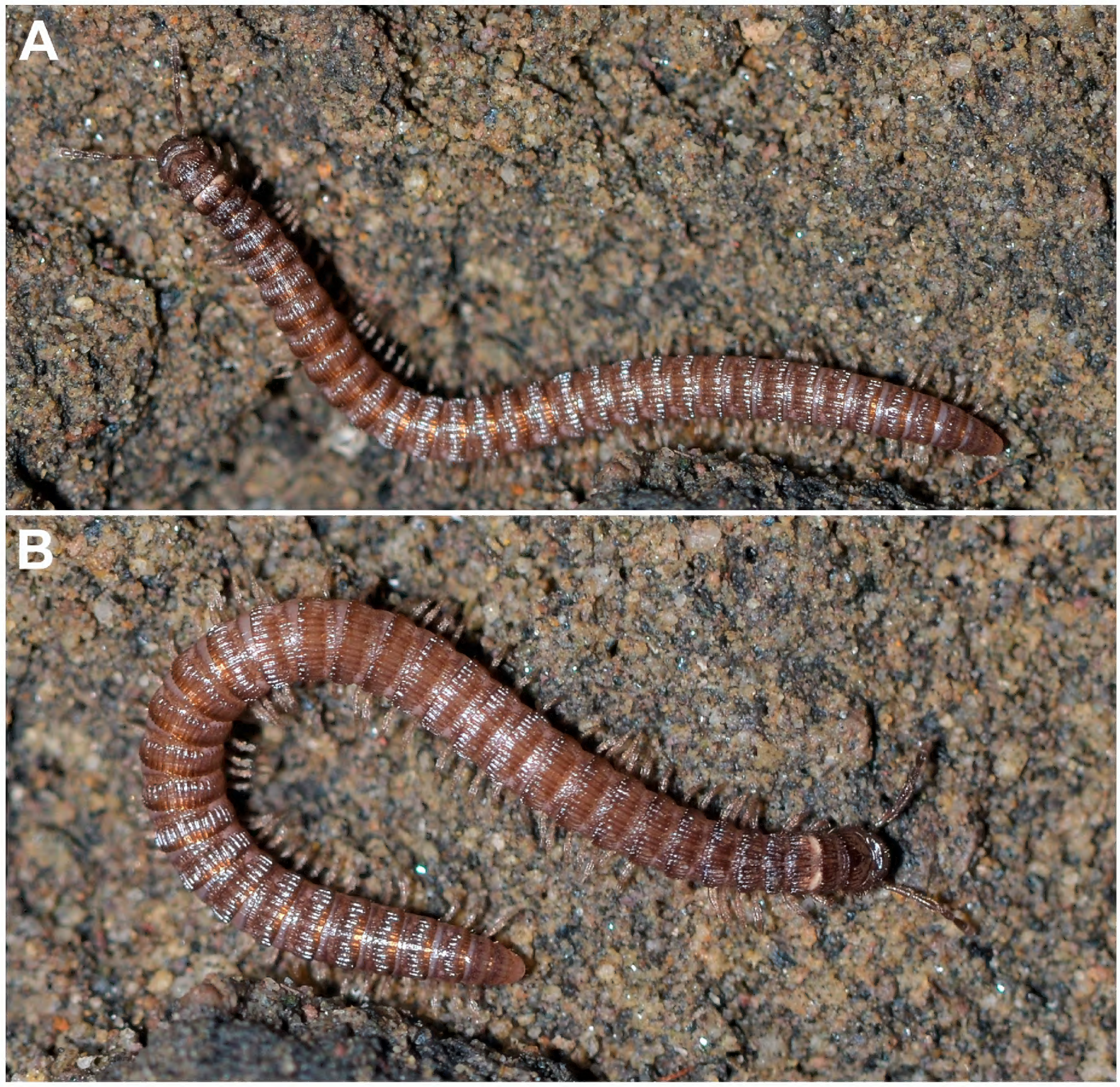

Figure 1. *Euxinopetalum dobatorum* Hoffman, 1973. **A, B:** female in situ (ABBM); **C:** cave plan with collection point.

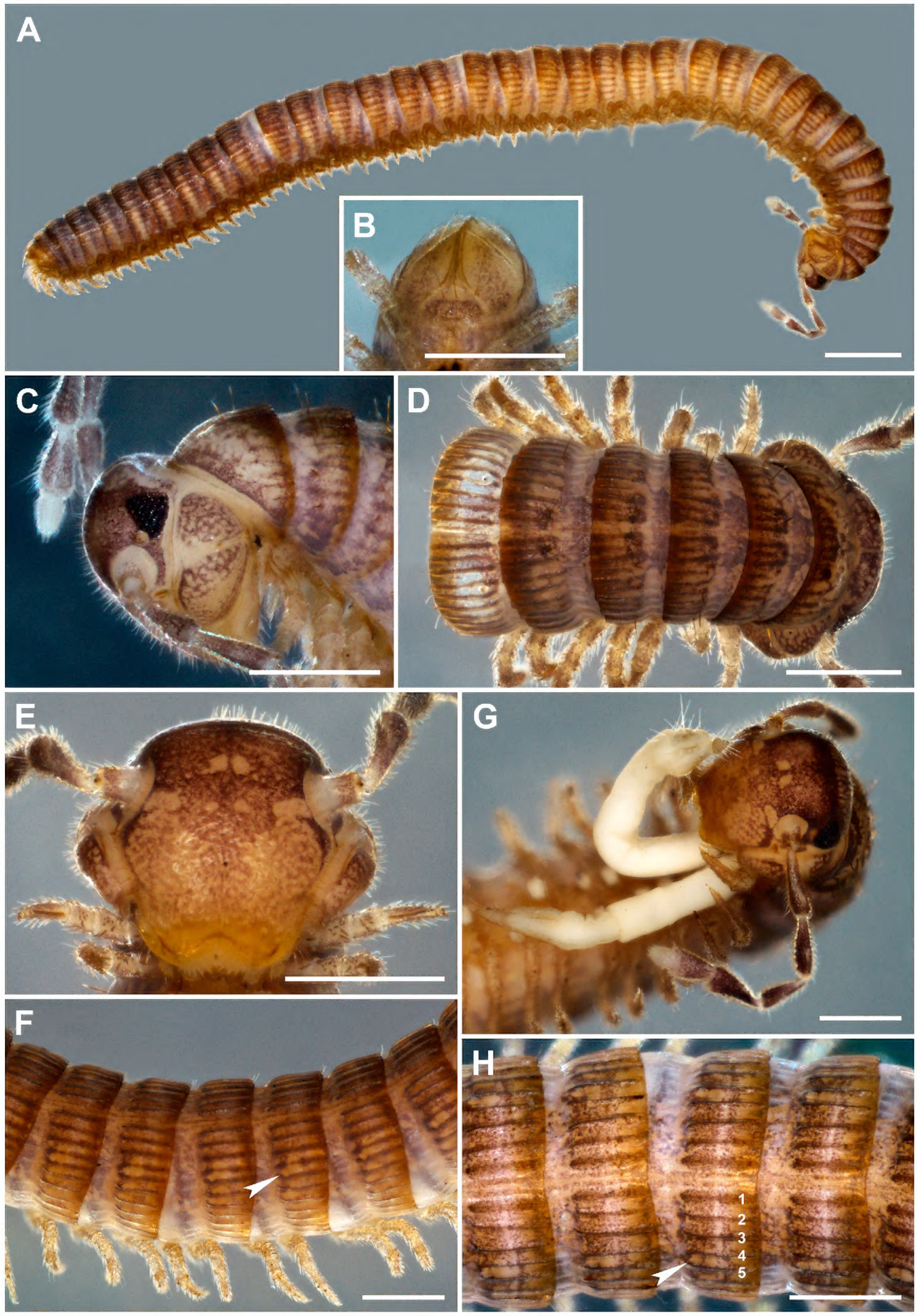

Figure 2. *Euxinopetalum dobatorum* Hoffman, 1973 habitus. **A:** male (ABBM), habitus, lateral view; **B:** female (ABBM), telson, ventral view; **C:** male (ABBM), anterior part of body, lateral view; **D:** male (IZB), anterior part of body, dorsal view; **E:** male (IZB), head, anterior view; **F:** male (NHMW MY10517), midbody segments, dorsolateral view; **G:** female (ABBM), anterior part of body, anterior and ventral view; **H:** female (ABBM), body segments 22–25, dorsal view. White arrows indicate ozopores. Scale bars = 1 mm (A), 0.5 mm (B–H).

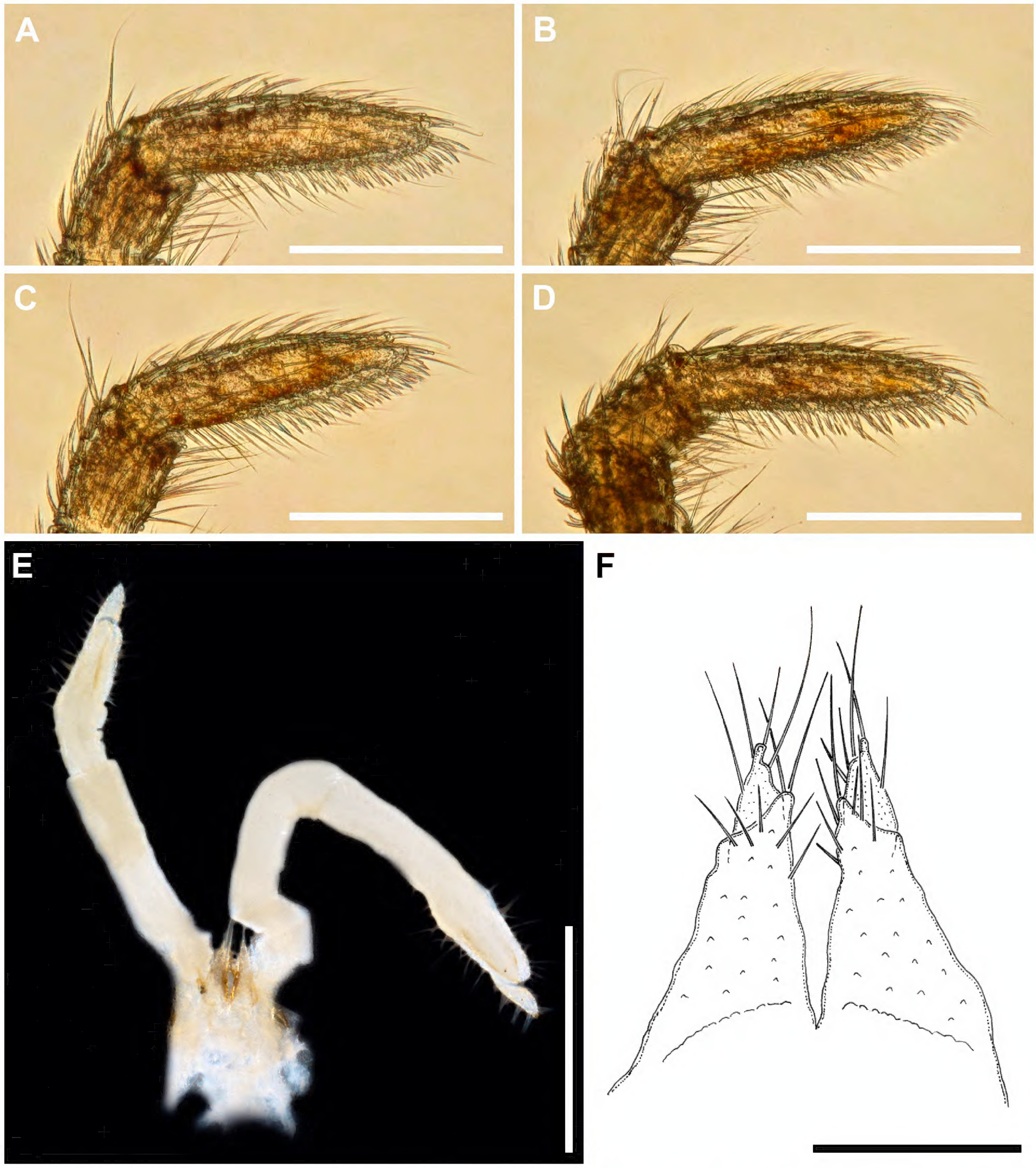

Figure 3. *Euxinopetalum dobatorum* Hoffman, 1973 male (IZB) and female (ABBM). **A–D:** left distal podomeres of male legs 4–7, respectively, anterior views; **E:** female leg pair 2 and vulvae, anterior view; **F:** female leg pair 2, anterior view. Scale bars = 1 mm (E), 0.2 mm (A–D, F).

medial process (mp) parallel to solenomere, and trifurcated, partly lamellar, mesal process (tp). Vulvae (Figs 2G, 3E) extruded very long, tubular. For a detailed description of the taxon, see Hoffman (1973: 85).

Habitat and distribution. This is apparently a troglophilic taxon. So far, it is known from two caves in the Zonguldak Province on the western Black Sea coast in Turkey. The original description contains no additional data for the two

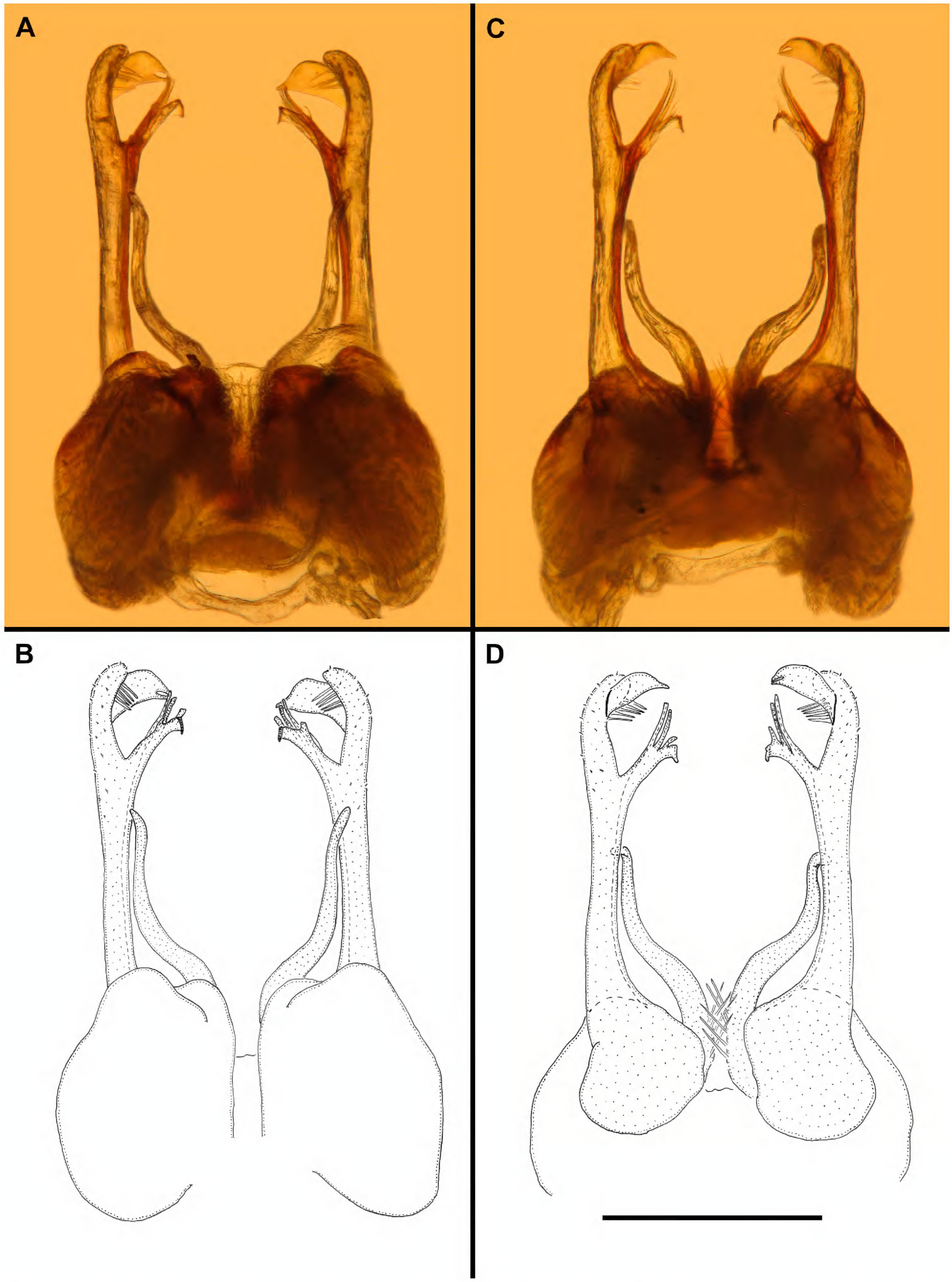

Figure 4. *Euxinopetalum dobatorum* Hoffman, 1973 male (IZB), gonopods. **A, B:** anterior view; **C, D:** posterior view. Scale bars = 0.3 mm.

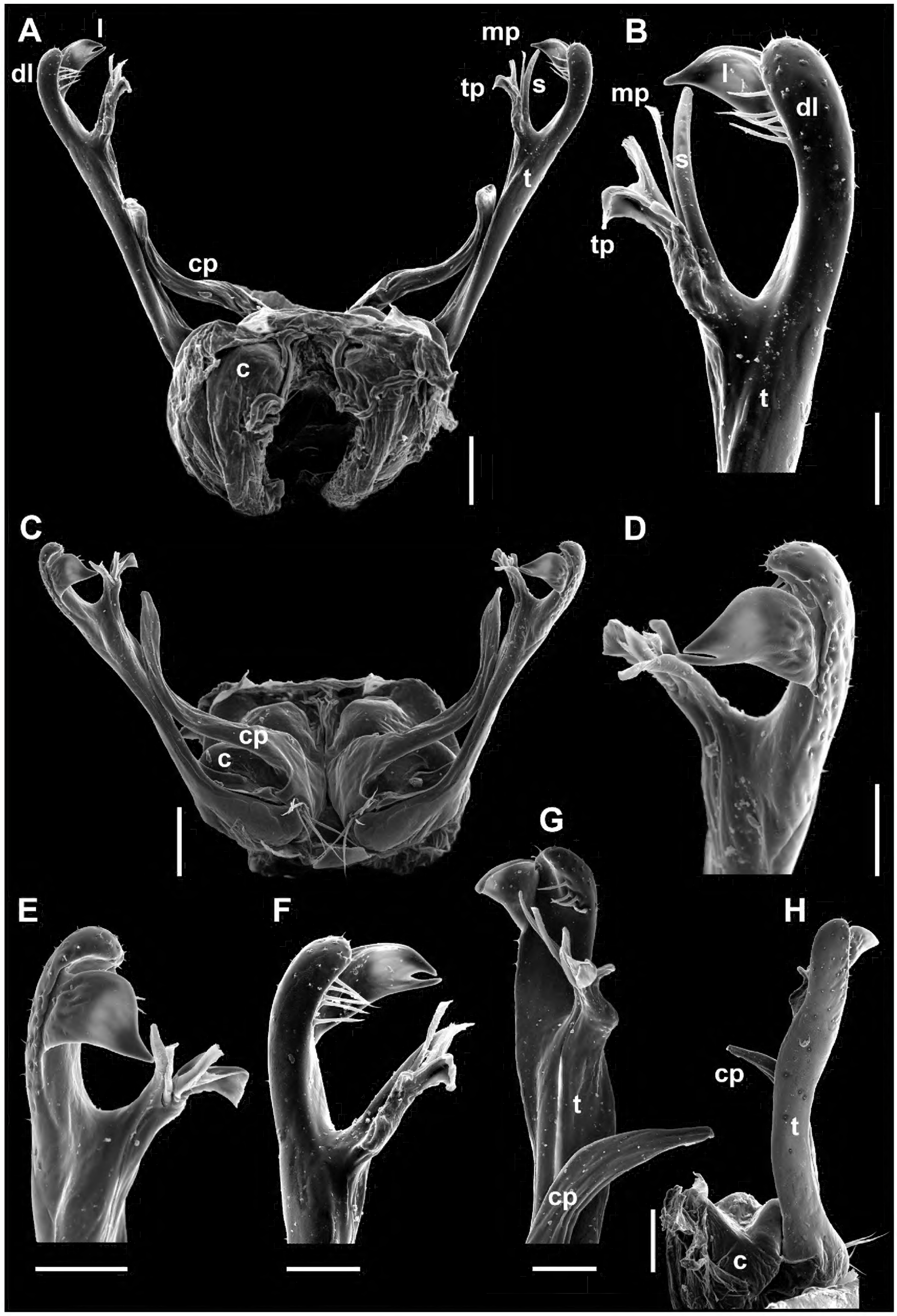

Figure 5. *Euxinopetalum dobatorum* Hoffman, 1973 male (IZB), gonopods. **A:** anterior view; **B:** distal part of right telopodite, anterior view; **C:** posterodistal view; **D:** distal part of left telopodite, posterodistal view; **E:** distal part of right telopodite, anterodistal view; **F:** distal part of left telopodite, anterior view; **G:** right telopodite and distal part of right coxal process, mesal view; **H:** lateral view. Abbreviations = c-coxa; cp-coxal process; dl-digitiform rounded lobe; l-lamella; mp-medial process; s-solenomere; t-telopodite; tp-trifurcated mesal process. Scale bars = 0.1 (A, C), 0.05 mm (B, D, E–H).

given localities. The type locality, Heracles Cave (see also discussion), is part of three closely located tourist caves or caverns with archeological significance, referred to as "Hell's Mouth Caves" in direct translation from Turkish (= Cehennemağzı Mağaraları). These caves are linked to Greek mythology, in particular with the story of Hercules (Heracles) and his descent into the Underworld. According to mythology, this is where Hercules entered Hades to capture Cerberus, the three-headed guard dog of the Underworld, as part of his Twelfth Labour (Demirtaş and Pınarcık 2016). The area is also associated with the ancient city of Herakleia Pontica, which was named after Hercules (the Turkish name Ereğli is a derivative of Herakleia). The caves hold historical and mythological significance and are visited by many people daily (Türker and Yaşar 2019). The complex consists of three caves: the Church Cave, Heracles Cave, and Ayazma Cave. They are sometimes referred to as the Acheron Caves, after the ancient name of the nearby river, further connecting the site to mythological depictions of the Underworld.

The main gallery of this tourist cave is severely transformed and illuminated. The new specimens were discovered in a fossil, narrow lateral passage that falls under the complete provision of the dark zone (Fig. 1C). The environment is characterized by an extremely low abundance of organisms, as is usual in an oligotrophic subterranean ecosystem, with roots occasionally penetrating the ceilings, reaching from the epigean ecosystem. The full list of taxa found in the Heracles Cave can be seen in Strouhal (1971: 379, 380) under the name "Höhle 2".

Remarks. The examination of recently collected specimens, consisting of three males and one female, generally agrees with the description of Hoffman (1973), with some exceptions. Hoffman (1973) states that the male and female are about 15 mm and 23 mm long, respectively, and have 38 segments each. The individuals from our sample are smaller, the males are 13–13.5 mm long, while the female is 15.5 mm long and they have two segments less, i.e. 36. As for the second pair of legs of the female, Hoffman (1973) states that these structures are only present in the form of "minute biramous vestiges". In the female we examined, the second pair of legs is indeed reduced and closely resembles Hoffman's (1973: 88, fig. 3) drawing, but with a clearly visible podomere and long setae on both parts. For this reason, it cannot be ruled out that Hoffman's female belongs to a different species. Finally, according to Hoffman (1973: 87, fig. 2), the mesal branch of the telopodite has four processes (labeled by him as 3, 4, 5, 6). However, what he described as process 6 is actually part of process 3.

To avoid confusion, the telopodite is attached to the posterior side of the coxa. Hoffman (1973: 85) incorrectly stated that "...telopodite attached on oral side of coxa...", but on the next page he correctly writes (Hoffman 1973: 86) "Telopodite attached on posterior side of coxa..."

Discussion

Most species of the order Callipodida are characterized by a medium-sized to large body. The largest representatives of this group come from the family Schizopetalidae, where some species from the genera *Eurygyrus* C.L. Koch,

1847, and *Apfelbeckia* Verhoeff, 1896 can grow 10 cm or more (Stoev et al. 2019; DA's personal observation). On the other hand, small species within the family Schizopetalidae exist but are not that common. *Euxinopetalum dobatorum* is not only one of the smallest Schizopetalidae, but also one of the smallest Callipodida, with males measuring 13–15 mm and females 15.5–23 mm. The only extant schizopetalid comparable to *E. dobatorum* is *Schizopetalum koelbeli* (Verhoeff, 1895) with a body size of 17.5–20 mm (Verhoeff 1895: 207). Miniature Callipodida are also found in the families Dorypetalidae (genus *Dorypetalum* Verhoeff, 1900) and Tynommatidae, with the smallest representatives measuring 12–13 mm (Enghoff et al. 2015). The small body size is usually associated with a reduced number of body segments. To our knowledge, the newly collected individuals of *E. dobatorum* with 36 segments (including the telson) are callipodidans with the lowest recorded number of segments in adults. To repeat, Hoffman (1973) recorded individuals of this species with 38 segments (including the telson). In addition to *E. dobatorum*, 38 segments were also recorded in *S. koelbeli* and *Callipodella vinciguerrae* (Silvestri, 1894) (Attems 1903; Silvestri 1894; Verhoeff 1895). It should be noted that Enghoff et al. (2015: 424) stated that the smallest Shizopetalidae is 12 mm long and that the smallest number of segments is 36 (35 pleurotergites and a telson). This information probably comes from Verhoeff (1897: 153), who clearly writes in the description of *Callipodella herzogowinesis* (Verhoeff, 1897) that he examined an adult female 12.5 mm long with 36 segments. Two years later, however, Verhoeff (1899: 227) stated for the same species that adult males and females have 42 segments and a 31–32 mm long body. At the same time, he (Verhoeff 1899) also mentioned a 12.5 mm long female with 36 segments in the list of juvenile specimens, which shows that the original description obviously referred to a juvenile female. However, Stoev et al. (2019: 87) specified that the number of "body rings" in *S. koelbeli* is 35–38, unfortunately without citing the source of the information. According to the literature data we checked, we could only find the number 38. It is interesting to point out that the recently described fossil species of Callipodida, *Burmanopetalum inexpectatum* Stoev, Moritz & Wesener, 2019 is the smallest species of the order, with a holotype female of 8.2 mm in length and with 36 segments. As hypothesized by Stoev et al. (2019), it cannot be ruled out that the small body and reduced number of body segments in Callipodida, including *E. dobatorum*, are features inherited from the ancestral form of Callipodida and Chordeumatida.

The distribution of *E. dobatorum* is, as we know, restricted to the western Black Sea coast of Turkey and the Zonguldak Province. In the original description Hoffman (1973: 87) gave as type locality: "Cave Nr. 2, Indere, 2 km northwest of Ereğli", without further details. Fortunately, he (Hoffman 1973: 82) wrote that Strouhal (1971) gave the exact locality and further details about the cave in which *E. dobatorum* was found when describing new isopod species. Based on the description and cave plan of "Höhle 2" in Strouhal (1971: 377, taf. 9), it is more than obvious that this is the same cave that is now known as Heracles Cave (compare taf. 9 with Fig. 1C). The second site mentioned by Hoffman (1973), the Kapuz Cave, is located in the city center of Zonguldak, about 40 km northeast of Ereğli. Such a distance between these records could, on the one hand, indicate a larger distribution range of this troglophilic species in the karst landscape of the western Black Sea, but due to some differences in

the structure of leg pair 2 in the females, it is also possible that we are dealing with two species.

As Antić (2023) emphasises, several new and little-known cave-dwelling taxa have been (re)discovered in recent years thanks to the efforts of Turkish cave biologists. Despite the fine description of the remarkable *E. dobatorum* by Hoffman (1973), we thought that new data and illustrations of the species would be worth publishing and would be helpful in future studies of the order Callipodida.

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Additional information

Conflict of interest

The authors have declared that no competing interests exist.

Ethical statement

No ethical statement was reported.

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Author contributions

DA initiated this study, took SEM photographs, made figure plates and wrote the first draft of the paper and together with TA and JM made photomicrographs, drawings and descriptive notes. ME collected the specimens, took in situ photographs and provided the collection site information. TA, JM and ME revised the final version of the manuscript.

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Data availability

All of the data that support the findings of this study are available in the main text or Supplementary Information.

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